REPORT R-1613

UNITED STATES ARMY

FRANKFORD ARSENAL

DEVELOPMENT AND ENGINEERING TEST OF NEW COOL BURNING EXTRUDED AND ROLLED BALL TYPE PROPELLANTS FOR 20MM AIRCRAFT AMMUNITION

by

A. Victor Nardi

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This report contains a Code Sheet

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DEVELOPMENT AND ENGINEERING TEST OF NEW COOL BURNING EXTRUDED AND ROLLED BALL TYPE PROPELLANTS FOR 20MM AIRCRAFT AMMUNITION

OMS Code

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INTRODUCTION

Contractor A successfully developed, under the direction of Frankford Arsenal, a cool burning, single base extruded propellant CR 7695 for use in 20mm aircraft ammunition. Frankford Arsenal Reports R-1449 and R-1470[1, 2*] describe the development and tests of this propellant CR 7695 and the various other single base extruded propellants that led up to its development. Following this development an attempt was made to improve the erosion characteristics of single base extruded propellant by two methods; namely, (a) obtaining a centralite coated propellant that develops a lower chamber pressure than CR 7695 when fired and (b) developing a new small arms extruded single base cool burning propellant type with a deterrent incorporated in the base grain.

Contractor A continued the developments under existing contract DA-36-034-507 ORD 125RD.[3]

These two new propellants were designated CR 7787 (the centralite coated propellant) and CR 7814 (the internally deterred and centralite coated propellant). A new rolled ball propellant designated X 2048 had also been developed by Contractor B for 20mm ammunition.[4] After satisfactory preliminary testing at Frankford Arsenal, combined engineering and erosion tests were fired at Aberdeen Proving Ground with these three propellants.

The details of the development of the extruded propellants CR 7787 and CR 7814 together with the results of the engineering and erosion tests at Aberdeen Proving Ground with these extruded propellants and rolled ball propellant X2048 are reported herein. Data has been previously reported to the customer by letter.[8]

METHOD

Development of Extruded Propellants

Contractor A,[3] technically supervised by Frankford Arsenal, was to develop cool burning extruded propellants that would be suitable for

*See References

use in 20mm aircraft ammunition. The first two phases of the development have been reported.[1,2] This report covers the third phase of the propellant development. The contractor, after consultation with representatives of Frankford Arsenal, prepared small (2 to 5 lb.) samples of propellant for testing. Initial tests (including closed bomb firings) were performed at the contractor's laboratory. When these tests indicated the propellants to be ballistically suitable, samples were forwarded to Frankford Arsenal for ballistic testing in Cartridge, Ball, 20mm, M55 at +70° F. After a review of the results of the ballistic tests of all the samples submitted to Frankford Arsenal, the two most satisfactory propellants were selected and larger samples were manufactured and subjected to more extensive tests at +70°, -70° and +165° F. Propellant CR 7695 developed under the second phase of this propellant development[2] was used as a control in these tests.

Engineering and Erosion Tests at Aberdeen Proving Ground with Experimental Propellants and Primer

Since the development of experimental double-base rolled ball propellant X2048[4] was completed about the same time as the development of extruded single base experimental-propellants CR 7787 and CR 7814, it was decided to combine the engineering and erosion tests of all three propellants at Aberdeen Proving Ground.

Since the development of the FAT 27E1 primer had also been completed[5] it was decided to load all the new propellants into cases primed with the FAT 27E1 primer. Therefore, these tests would also serve as engineering and erosion tests of the new primer. Additionally, these tests became an evaluation of ignition systems rather than evaluations of specific propellant or primer types.

The first four of the following listed lots of Cartridges, Ball, 20mm, M55 type were loaded at Frankford Arsenal and forwarded to Aberdeen Proving Ground for test.[6] The fifth lot was supplied by Aberdeen Proving Ground as a control and contained the standard WC 870 propellant and M52A3B1 primer.

Lot No.	Propellant	Primer	Quantity
FA-X20-2767	CR7695 Lot 3	FAT27E1	12,000
FA-X20-2768	CR7787 Lot 4	FAT27E1	12,000
FA-X20-2769	CR7814 Lot 2	FAT27E1	12,000
FA-X20-2770	X2048	FAT27E1	10,000*
KOP 153-18	WC870AL40378	M52A3B1	-

*NOTE - Only 10,000 rounds of lot FA-X20-2770 were loaded at this time because it was desired to hold the remaining quantity of propellant X2048 for other possible ballistic tests. An additional quantity of approximately 3500 rounds was shipped to APG at a later date.

All five lots of 20mm ammunition were subjected to the following test program at Aberdeen Proving Ground.

	Total Rounds to be Tested Per Lot Per Test			
Test	Fired at +70° F	Fired at -70° F	Fired at +165° F	Total Rds. Per Lot
Pressure, Velocity and Action Time (Gage)	20	20	20	60
Velocity (M39 Machine Gun)	20	20	20	60
Erosion (M39 Machine Gun) (See Narrative Below)				

The erosion test was fired in the M39 machine gun using a schedule of 125-round bursts with 30-second cooling between bursts and complete cooling after every 250 rounds. A barrel was disqualified when (a) the average velocity of any 20 consecutive cartridges of a burst was 6% or more below the average velocity of the first 20 round burst fired in the

new barrel; or (b) yaw of 15 degrees or more is encountered with 20 percent or more of any consecutive 40 rounds of any burst. Five barrells were to be fired to completion with each lot of ammunition if sufficient rounds were available.

DISCUSSION OF RESULTS

Development of Extruded Propellants

The quarterly reports and the final report submitted by Contractor A[3] give a detailed account of the progress of the 20mm extruded propellant development. During the entire period of the development, the contractor prepared and tested at his laboratory approximately 350 experimental 20mm propellants. The twenty different basic compositions utilized are listed in the contractor's final report. Those samples that were found to be ballistically suitable for 20mm ammunition by closed bomb firings and limited ballistic testing at the contractor's laboratory were submitted to Frankford Arsenal for ballistic testing in Cartridge, Ball, 20mm, M55. During this phase of the propellant development, 24 such preliminary samples were found suitable at the contractor's laboratory and were submitted to Frankford Arsenal. Table I lists the identity, composition, granulation, flame temperature and the initial ballistic performance at Frankford Arsenal of these samples. It should be noted that in some instances propellant samples with the same composition and granulation gave vastly different ballistics. This is because the compositions listed are nominal and do not reflect the actual propellant composition. These samples were produced in the contractor's semi-works and were 2 to 5 lbs. with the result that they were generally exhausted in ballistic testing so that chemical analysis could not be made. Such a chemical analysis would have probably indicated large differences in the amount of deterrent actually present in the samples.

After reviewing the results listed in Table I, it was concluded that propellant Ex7787* gave the most satisfactory ballistic results of the

*It might be well to note at this point that the contractor identifies his experimental propellant samples with Ex numbers. However, if a sample type leads to an acceptable propellant type, the Ex is changed to CR (Cool Rifle). Therefore, propellants Ex 7787 and 7814 will be later identified as Cr 7787 and 7814.

Table No. I

Table Showing Identity, Composition, Granulation, Calculated Flame Temperature and Ballistic Performance of Various, Single Base, Extruded, Experimental Propellants When Tested in Cartridge, 20mm, Ball, M55. Ballistic Requirement: 3380 ± 50 f/s Within a Maximum Average Pressure of 50,000 psi With An Action Time Not To Exceed 3.5 m. s. When Fired In A Pressure Gage

Propellant Designation	Propellant Composition and Granulation (Nominal in Parts)	Calculated Flame Temp. °K	Propellant Charge grs	Primer	Gage Firing			Remarks
					Action Time ms	Short Piston Vel. f.s.	Pressure psi	
Ex7756	100 Nitrocellulose; 1 DPA; 1 K_2SO_4; 1 Tin Coated 6 DNT and 5 DBP; 0.056" - 0.15" x 1/16"	2510	560 (full case)	M52A3B1	5.52	3272	48200	Unsuitable, Low Velocity and High action time
Ex7757	100 Nitrocellulose; 1 DPA; 1 K_2SO_4; 1 Tin Coated 6 DNT and 4 DBP; 0.060" - 0.015" x 1/16"	2590	568 (full case)	M52A3B1	4.74	3321	48700	Unsuitable, Low Velocity and High action time
Ex7758	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 6 Cent. No. 2 0.070" - 0.015" x 1/16"	2450	575 (full case)	M52A3B1	2.83	3360	53500	Satisfactory, contractor will supply additional sample
Ex7759	100 Nitrocellulose; 2.5 DBP; 1 DPA; 1 K_2SO_4; 1 Tin Coated 7 Cent. No. 2 0.060" - 0.015" x 1/16"	2340	555 (full case)	M52A3B1	4.05	3315	51900	Unsuitable, Low Velocity and High action time
Ex7764	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 5-1/2 Cent. No. 2 0.070" - 0.015" x 1/16"	2485	560 (full case)	M52A3B1	3.15	3201	46400	Unsuitable, Low Velocity Sample not ballistically similiar to Ex7758 contractor will make new sample
Ex7760	100 Nitrocellulose; 2 K_2SO_4; 1 DPA; 1 Tin Coated 8 Cent. No. 2 0.065" - 0.015" x 1/16"	2470	590 (full case)	M52A3B1	2.99	3340	56900	Unsuitable, Low Velocity
Ex7763	100 Nitrocellulose; 2 K_2SO_4; 1 DPA; 1 Tin Coated 6 Cent. No. 2 0.075" - 0.015" x 1/16"	2600	570 (full case)	M52A3B1	2.78	3397	56800	Maybe suitable, contractor will make additional sample
Ex7761	100 Nitrocellulose; 2 K_2SO_4; 1 DPA; 1 Tin; 15 DNT Double Coated 0.070" - 0.015" x "/16"	-	568 (full case)	M52A3B1	3.27	3314	51400	Unsuitable, Low Velocity
Ex7762	100 Nitrocellulose; 2 K_2SO_4; 1 DPA; 1 Tin Coated 7.5 DNT and 4.0 Cent. No. 2 0.065" - 0.015" x 1/16"	-	560 (full case)	M52A3B1	2.98	3365	60700	Unsuitable, High Pressure
Ex7786	100 Nitrocellulose; 2 K_2SO_4; 1 DPA; 1 Tin; Double Coated 6 Cent. No. 2 and 4 DNT 0.070" - 0.015" x 1/16"	-	578	M52A3B1	3.19	3416	55400	Unsuitable, High action time
Ex7787	100 Nitrocellulose; 2 K_2SO_4; 1 DPA; 1 Tin Coated 6 Cent. No. 2 0.075" - 0.015" x 1/16"	2610	570	M52A3B1	2.94	3384	53700	Satisfactory, contractor will supply additional sample
Ex7788	100 Nitrocellulose; 2 K_2SO_4; 1 DPA; 1 Tin Coated 5 Cent. No. 2 0.075" - 0.015" x 1/16"	2680	570	M52A3B1	3.00	3419	56200	Unsuitable, action time high

NOTE: Abbreviations

DPA: Diphenylamine
K_2SO_4: Potassium Sulfate
DBP: Dibutyl Phthalate

Table No. I (Cont'd)

Propellant Designation	Propellant Composition and Granulation (Nominal in Parts)	Calculated Flame Temp. °K	Propellant Charge grs	Primer	Gage Firing Action Time ms	Gage Firing Short Piston Vel. f. s.	Gage Firing Pressure psi	Remarks
Ex7789	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 4 Cent. No. 2 0.070" - 0.015" x 1/16"	2590	587 (full case)	M52A3B1	3.17	3289	45100	Unsuitable, Low Velocity
Ex7790	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 6 Cent. No. 2 0.070" - 0.015" x 1/16"	2450	580 (full case)	M52A3B1	3.69	3023	32000	Unsuitable, Low Velocity, High action time
Ex7796	Not available	-	565	M52A3B1	3.03	3330	514000	Unsuitable, Low Velocity
Ex7802	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 6 Cent. No. 2 0.070" - 0.015" x 1/16"	2450	580 (full case)	M52A3B1	-	3183	45500	Unsuitable, Low Velocity
				FAT36E7 Lot H	2.87	3220	47300	
Ex7803	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 6 Cent. No. 2 0.070" - 0.015" x 1/16"	2450	580 (full case)	M52A3B1	11.65	3048	37100	Unsuitable, Low Velocity
				FAT36E7 Lot H	3.28	3139	39700	
Ex7804	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 5 Cent. No. 2 0.070" - 0.015" x 1/16"	2520	585 (full case)	M52A3B1	2.95	3284	46100	Unsuitable, Low Velocity
				FAT36E7 Lot H	2.75	3312	51400	
Ex7810	98 Nitrocellulose, 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 4 Cent. No. 2 0.070" - 0.015" x 1/16"	-	585 (full case)	M52A3B1	-	3403	57900	Satisfactory, However Pressure High
Ex7811	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 5 Cent. No. 2 0.070" - 0.015" x 1/16"	-	585 (full case)	M52A3B1	2.79	3384	57200	Satisfactory, However Pressure High
Ex7812	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 4 Cent. No. 2 0.070" - 0.015" x 1/16"	-	585 (full case)	M52A3B1	3.71	3273	45500	Unsuitable, Low Velocity
Ex7813	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 5 Cent. No. 2 0.070" - 0.015" x 1/16"	-	585 (full case)	M52A3B1	3.29	3177	40400	Unsuitable, Low Velocity
Ex7814	98 Nitrocellulose; 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 4 Cent. No. 2 0.070" - 0.015" x 1/16"	2580	585 (full case)	M52A3B1	2.87	3350	50500	Satisfactory
Ex7815	98 Nitrocellulose, 2 DBP; 2 K_2SO_4; 1 DPA; 1 Tin Coated 4.5 Cent. No. 2 0.070" - 0.015" x 1/16"	-	585 (full case)	M52A3B1	3.01	3289	47400	Unsuitable, Low Velocity

NOTE: Abbreviations

DPA: Diphenylamine
K_2SO_4: Potassium Sulfate
DBP: Dibutyl Phthalate

centralite coated samples, while the Ex7814 propellant gave the best ballistics of the internally deterred and coated samples. Accordingly, additional samples of propellants Ex7787 and Ex7814 were obtained from Contractor A for a temperature coefficient test in Cartridge, Ball, 20 mm, M55. Since the Ex7787 propellant gave a much better ballistic relationship with the newly developed FAT 27E1 primer** than with the standard M52A3B1 primer, the new primer was used with this propellant while the standard primer was used with the Ex7814 propellant and with the control ammunition which was loaded with CR7695 propellant.

The results of the tests fired at +70°, -70° and +165° F are given in Table II. These results show that propellant Ex7787 with FAT 27E1 primer gave the best results with a spread of only 103 feet in mean velocity over the temperature range of -70° to +165° F. The other two experimental single base propellants (CR7695 and Ex7814 both with M52A3B1 primers) also gave good results, the spread in velocity being 162 feet and 184 feet respectively. It should be noted the normal spread over the temperature range with the standard ammunition loaded with ball WC870 propellant with M52A3B1 primers is between 250 and 350 feet per second.

Since both experimental propellants (Ex7787 and Ex7814) appeared to have temperature coefficients better than the standard propellant (WC870), it was decided to procure a sufficient quantity of both propellants from Contractor A in order that ammunition could be loaded and engineering and erosion tests fired at Aberdeen Proving Ground. A quantity of propellant CR7695 was also ordered from this contractor to be loaded into control ammunition for these tests.

Engineering and Erosion Tests at Aberdeen Proving Ground with Experimental Propellants and Primers

1. Ballistic Tests

Table III gives the results of the ballistic tests fired in the gage and the M39 machine gun at +70°, -70° and +165° F.

**FAT 27E1 Primer is FAT 36E7 Primer with modified hardware (see ref. 5).

TABLE II

Table of Ballistic Data Showing Results after Storage for a Minimum of 2 Hours at the Required Temperature
All firings in Gage with Cartridge Ball, 20 mm, M55

Propellant Ex7814, Charge 585 grs, Primer M52A3B1

Temp. -°F of Firing	Action Time ms	Velocity f/s	SD f/s	Pressure psi	SD psi
70	2.86	3367	12	53100	1500
-70	3.12	3252	19	46700	1600
+165	2.82	3436	12	58000	1600

Temperature Coefficient (-70° to +165° F) = 0.78 f/s/°F

Propellant Ex7787-1, Charge 570 grs, Primer FAT36E7
(Now FAT27E1 Type)

Temp. -°F of Firing	Action Time ms	Velocity f/s	SD f/s	Pressure psi	SD psi
70	2.72	3370	13	52900	1500
-70	2.92	3300	37	51000	3400
+165	2.73	3403	19	54100	2100

Temperature Coefficient (-70° to +165° F) = 0.44 f/s/°F

Propellant CR7695-1, Charge 566 grs, Primer M52A3B1

Temp. -°F of Firing	Action Time ms	Velocity f/s	SD f/s	Pressure psi	SD psi
70	2.75	3390	12	56100	2300
-70	3.05	3281	28	49800	3000
+165	2.69	3443	15	58100	2400

Temperature Coefficient (-70° to +165° F) = 0.69 f/s/°F

TABLE No. III

Results of Ballistic Tests at +70°, -70° and +165° F

Lot FA 2767

CR7695 Lot 3; Propellant Charge 555 grs; Primer FAT 27E1

Temp. °F of Firing	Machine Gun Velocity f. s.	Machine Gun SD f. s.	Action Time m. s.	E. V. m. s.	S. P. Velocity f. s.	Gage SD f. s.	Pressure psi	SD psi	F. A. Gage Acceptance S. P. Velocity f. s.	F. A. Gage Acceptance Pressure psi
+70	3212	19	2.53	0.22	3327	18	57900	2200	3350	57800
-70	3167	25	2.72	0.25	3308	13	60500	2500		
+165	3264	14	2.55	0.13	3345	7	58200	1700		

Lot FA 2768

CR7787 Lot 4; Propellant Charge 578 grs; Primer FAT 27E1

Temp. °F of Firing	Machine Gun Velocity f. s.	Machine Gun SD f. s.	Action Time m. s.	E. V. m. s.	S. P. Velocity f. s.	Gage SD f. s.	Pressure psi	SD psi	F. A. Gage Acceptance S. P. Velocity f. s.	F. A. Gage Acceptance Pressure psi
+70	3198	25	2.73	0.12	3354	13	53800	1400	3383	55300
-70	3079	37	2.98	0.34	3269	22	48700	2800		
+165	3238	12	2.74	0.11	3373	14	57100	1400		

Lot FA 2769

CR7814 Lot 2; Propellant Charge 573 grs; Primer FAT 27E1

Temp. °F of Firing	Machine Gun Velocity f. s.	Machine Gun SD f. s.	Action Time m. s.	E. V. m. s.	S. P. Velocity f. s.	Gage SD f. s.	Pressure psi	SD psi	F. A. Gage Acceptance S. P. Velocity f. s.	F. A. Gage Acceptance Pressure psi
+70	3219	22	2.72	0.13	3357	9	54200	1400	3378	54800
-70	3109	32	2.95	0.30	3269	17	49600	2000		
+165	3245	14	2.72	0.08	3364	6	56200	1000		

Lot FA 2770

X2048; Propellant Charge 588grs; Primer FAT 27E1

Temp. °F of Firing	Machine Gun Velocity f. s.	Machine Gun SD f. s.	Action Time m. s.	E. V. m. s.	S. P. Velocity f. s.	Gage SD f. s.	Pressure psi	SD psi	F. A. Gage Acceptance S. P. Velocity f. s.	F. A. Gage Acceptance Pressure psi
+70	3179	26	2.93	0.18	3317	12	54100	1300	3357	54200
-70	3088	18	3.02	0.37	3236	23	56600	2500		
+165	3164	32	2.93	0.27	3281	22	50700	1800		

Lot KOP 153-18

(Badger) WC 870 AL 40378; Propellant Charge, Primer M52A3B1

Temp. °F of Firing	Machine Gun Velocity f. s.	Machine Gun SD f. s.	Action Time m. s.	E. V. m. s.	S. P. Velocity f. s.	Gage SD f. s.	Pressure psi	SD psi
+70	3284	30	2.55	0.09	3362	12	50000	1000
-70	3047	22	2.78	0.19	3215	33	57100	2568
+165	3402	10	2.41	0.06	3505	8	60800	1200

Table IV lists the temperature coefficients in machine gun velocity, gage velocity, pressure and action time over the temperature range of -70° to +165° F from the data presented in table III.

It should be noted that all four of the experimental propellants gave temperature coefficients which were much smaller than the standard 20mm ammunition lot KOP-153-18. All propellants were loaded into 20mm ammunition which was primed with the new FAT27E1 electric primer, while the standard ammunition with the WC870 propellant was primed with the M52A3B1 electric primer. Although there are slight differences in the temperature coefficients of the four experimental propellants, it is believed that slight modifications of the FAT27E1 primer to suit each propellant would result in practically the same temperature coefficient with each of these experimental propellants. It should be noted that the short piston velocities recorded at Aberdeen Proving Ground for the lots of cartridges loaded at Frankford Arsenal were all lower than the short piston velocities recorded at Frankford Arsenal at the time of loading.

2. Erosion Tests

The results of the erosion tests with the five lots of ammunition are contained in table V.

The three single base extruded cool burning propellants gave very good uniformity of erosion end point in the tests.

The average erosion life of four barrels with propellant CR7695, Lot 3 (Lot FA-X20.2767) was 2113 rounds. When this type propellant was previously tested for erosion a barrel life of 1723 rounds was obtained. The increase in barrel life may have been due to the lower flame temperature of CR7695, Lot 3. The propellant description sheets (see Appendix) indicate that the two lots of CR7695 had slightly different percentages of methyl centralite coating. The higher percentage of methyl centralite in Lot 3 resulted in about a 60° decrease of the flame temperature.

The other two experimental single base propellants CR7814 (Lot FA-X20-2769) and CR7787 (Lot FA-X20-2768) gave essentially the same average barrel life for four barrels; CR7814 - 2573 rounds and CR7787 - 2558 rounds. All three of the experimental single base propellants developed by Contractor A have approximately the same flame temperature, CR7695 Lot 3 - 2590° K; CR7787 Lot 4 - 2590° K, and

Table IV. Table of Differences of Test Data

(Range from -70° F to +165° F)

Lot No.	Propellant	Machine Gun Velocity M39		Gage Velocity		Pressure	Action
		Difference f/s	Temp. Coef.	Difference f/s	Temp. Coef.	psi	time-ms
FA-X20-2767	CR7695	97	0.41	37	0.16	2600	0.19
FA-X20-2768	CR7787	159	0.68	104	0.44	8400	0.25
FA-X20-2769	CR7814	136	0.58	95	0.40	6600	0.23
FA-X20-2770	X2048	91	0.39	81	0.34	5900	0.09
KOP153-18	WC870	355	1.51	290	1.23	10900	0.37

Table V. Results of Erosion Tests

Lot No.	Propellant	Barrel No.	Disqualification Point	Reason for Disqualification	Average Disqualification Point
FA-X20-2767	CR7695	295590	1950 rds	Excessive velocity loss	
ditto	ditto	295505	2020 rds	ditto	
ditto	ditto	295511	2000 rds	ditto	
ditto	ditto	295571	2480 rds	ditto	2113 rds
FA-X20-2768	CR7787	259237	2585 rds	Excessive velocity loss	
ditto	ditto	259161	2645 rds	ditto	
ditto	ditto	295593	2250 rds	ditto	
ditto	ditto	295605	2750 rds	ditto	2558 rds
FA-X20-2769	CR7814	259010	2395 rds	Excessive velocity loss	
ditto	ditto	295606	2645 rds	ditto	
ditto	ditto	295460	2605 rds	ditto	
ditto	ditto	295504	2645 rds	ditto	2573 rds
FA-X20-2770	X2048	259043	6250 rds*	Test discontinued Barrel still satisfactory	
ditto	ditto	258868	1950 rds	Excessive Yaw	**
ditto	ditto	295480	5000 rds*	Test discontinued Barrel still satisfactory	4400+ rds
KOP153-18	WC870	259058	2835 rds	Excessive velocity loss	
ditto	ditto	295488	3625 rds	ditto	
ditto	ditto	259253	3480 rds	ditto	
ditto	ditto	295471	2740 rds	ditto	3170 rds

*Barrel not disqualified test discontinued because of lack of ammunition.

**Average of one disqualified barrel and two barrels in which test was discontinued.

CR7814 Lot 2 - 2580° K. The longer barrel life obtained with propellants CR7787 and CR7814 may be partially attributable to the fact that the chamber pressure developed with these two propellants is approximately 4000 psi lower than the chamber pressure developed by propellant CR7695.

The experimental double base rolled ball propellant X2048 (Lot FA-X20-2770) was erosion tested in three barrels. Two of these barrels, No. 259043 and No. 295480 were fired 6250 rounds and 5000 rounds respectively and were still serviceable when firing was discontinued due to lack of ammunition. As far as is known these two barrels yielded the longest barrel life attained in M39 erosion testing in the United States. The third barrel, No. 258868, was disqualified because of excessive yaw after 1950 rounds were fired. No cause could be determined for the early failure of this barrel. Dimensionally there appeared to be no significant difference among the three barrels fired and examination of the bore after firing did not reveal any condition to which the failure of Barrel No. 258868 could be attributed. Erosion of the bore surface was light and evidently was not a factor in determining life of this barrel.

The reason that two barrels were not fired to completion because of lack of ammunition with Lot FA-X20-2770, was that originally, in accordance with the established procedure at Aberdeen Proving Ground three barrels were started simultaneously in the erosion test and were fired alternately; that is, a cycle was fired with one barrel and while it was cooling another barrel was fired, then a cycle.

When the three barrels had each reached the 1750 round point it was decided to continue firing one barrel at a time because of the limited supply of ammunition. The ammunition was exhausted when barrel No. 259043 had reached the 6250 round point. Then all of the X2048 propellant remaining at Frankford Arsenal was loaded into ammunition resulting in an additional 3500 rounds being sent to Aberdeen Proving Ground. Barrel No. 258868 was fired to disqualification at 1950 rounds and the remaining ammunition was fired in barrel No. 295480 in which the total reached 5000 rounds without disqualification. No more rounds were fired in Barrel No. 259043 because it was believed additional firing would not add to the engineering data.

There were two differences which were probably responsible for the improvement in the erosion characteristics of the rolled X2048

propellant over those observed with WC870 ball propellant. The X2048 propellant has a lower flame temperature than the conventional ball propellant and it does not contain the antifoulant tin-dioxide. Instead of tin-dioxide a cool deterrent was used which contributed to the lower flame temperature. These erosion tests indicated that there were apparently no ill effects caused by the removal of the antifoulant from the X2048 propellant. Smoke, fouling and flash tests will be fired in the final engineering tests.

The average erosion life for four barrels with the control ammunition with propellant WC870 (KOP-153-18) was 3170 rounds. This is considered average for this type of ammunition.

The improvements with respect to erosion with the three new propellants were significant. The rolled ball propellant was superior to the conventional ball propellant WC870 and the new single base extruded propellants (CR7814 and CR7787) were superior to the CR7695 propellant.

CONCLUSIONS

It is concluded that:

a. With respect to erosion characteristics the new single base extruded cool burning propellants (CR7787 and CR7814) in Cartridge Ball, 20mm, M55 with FAT27E1 primer are greatly superior to IMR7005 propellant and are superior to the previously developed single base cool burning propellant CR7695. Propellants CR7787 and CR7814 apparently meet all the requirements for 20mm aircraft ammunition.

b. With respect to erosion characteristics the new double base rolled ball propellant X2048, in Cartridge, Ball, 20mm, M55 with FAT FAT27E1 primer is superior to the standard ball propellant WC870. Propellant X2048 apparently meets all the requirements for 20mm aircraft ammuntion.

c. The new primer FAT27E1 offers a substantial improvement in the ballistic characteristics of 20mm ammunition with respect to high and low temperature firings. Primer FAT27E1 apparently meets all the requirements for 20mm aircraft ammuntion.

RECOMMENDATIONS

It is recommended that:

a. Final engineering and user tests be made with one or both of the single base cool burning extruded propellants CR7787 or CR7814.

b. Final engineering and user tests be made with rolled ball propellant X2048.

c. Final engineering and user tests be made with primer FAT27E1.

d. Consideration be given to modification of the FAT27E1 primer to suit each individual propellant type prior to final engineering and user tests.

REFERENCES

1. Frankford Arsenal Report No. R-1449 "Ballistic Performance of Newly Developed Cool Burning Extruded and Ball Type Propellants in Cartridge 20mm Ball M55 and 20mm APIT M52," by A. V. Nardi and Pfc H. B. Whitmore, Jr., July 1958.

2. Frankford Arsenal Report No. R-1470 "Development of Cool Burning, Single Base, Extruded Propellant for 20mm Aircraft Ammunition," by A. V. Nardi and E. Beugless, January 1959.

3. Contractor A, Contract DA-36-034-507-ORD-125RD, Final Report dated 31 December 1959.

4. Frankford Arsenal Report No. R-1600 "Reduction of the Temperature Coefficient of Ballistics of 20mm Aircraft Ammunition," by M. E. Levy, August 1961.

5. Frankford Arsenal Report R-1479B, "Development of an Improved Electric Primer for 20mm Ammunition and Barrel Heat Input Studies using 20mm Aircraft Ammunition," by R. Donnard and W. Colley, to be published.

6. Letter ORDBA-1451 Subject "Ballictic Tests of 20mm Aircraft Ammunition Propellants at A. P. G." dated 11 Oct 1960 to OCO Attn: ORDTS.

7. Development and Proof Services, Aberdeen Proving Ground Firing Record No. S-46387.

8. Letter Frankford Arsenal to Hill Air Force Base, Attn: OOYES and OOYIT dated 13 July 1961.

APPENDIX

OD FORM 1204, 15 Apr. 52

ORDNANCE CORPS
PROPELLANT DESCRIPTION SHEET

Supersedes OD Form 1204 dated 1 Jul. 49 which is obsolete.

U.S. Army Lot No. Not Issued of 1960 Composition No. CR-7695 Per 20 mm
Lot 3 of E. I. du Pont de Nemours & Co., Inc
Manufactured at: Packed Weight 1500 #
Contract No. Date Specification No. Revision of

NITROCELLULOSE DA-36-038-507-ORD-3413/N

Accepted blends (Nos.) 2214

Nitrogen Content	K. I. Starch Test (65.5° C.)	Stability Test (135° C.)
Maximum %	Maximum Mins.	Maximum Mins.
Minimum %	Minimum Mins.	Minimum Mins.
Average 13.14 %	Average 37 Mins.	Average 30 Mins.
		Explosion Mins.

MANUFACTURE OF PROPELLANT

Total weight of solvent per pound NC 0.92 Consisting of 35 pounds alcohol and 65 pounds ether per 100 pound solvent. Percentage of results to whole

TEMPS. °C From	TEMPS. °C To	PROCESS—SOLVENT RECOVERY AND DRYING	TIMES From	TIMES Hours
35	55	Solvent Recovery		20
	55	Water drying, before coating	3	
	55	Water drying, after coating		24
	55	Air drying		18

TESTS OF FINISHED PROPELLANT

COMPOSITION % Constituent	% Pounds	% Mfr.	% Impr.
Nitrocellulose	100.0	91.41	
Potassium Sulphate*	1.0	1.03	
Pulverized Tin*	1.0	0.95	
Diphenylamine*	1.0	0.71	
Centralite No. 2		5.74	
Total volatiles		1.02	
Moisture (CCl4 dist)		0.80	
Ash		0.10	
Residual Solvent		0.22	

STABILITY AND PHYSICAL TESTS	Mfr.	Impr.
135° C heat test, E. P.	35'	
Explosion	5+	
Form of grain	Cylindrical	
No. of perforations	1	
No. of grains per pound	204,030	
Burning surface per pound (sq. inches)	2534	
Grav. density, [illegible]	933	
[illegible] Dust & fgn mat	0.02%	
Hygroscopicity		
[illegible] Graphite	0.14%	

GRAIN DIMENSIONS	DIE (INCHES)	FINISHED GRAIN (INCHES) Manufacturer	FINISHED GRAIN (INCHES) Inspector	MEAN VARIATION IN PER CENT OF MEAN DIMENSION Manufacturer	MEAN VARIATION IN PER CENT OF MEAN DIMENSION Inspector
Length (L)	.0606	.0581			
Diameter (D)	.0650	.0443			
Diameter of perforations (d)	.0150	.0073			
Web: Inner					
Web: Outer					
Web: Average	.0250	.0185			
Web: Calculated					
Difference between inner and outer web in per cent of web average					
L:D (Y)					
D:d (X)					

Date packed 9/26/60 Date offered Date sampled
Date test finished Date description sheets forwarded
Type of Packing Box Tinned-copper lined boxes
Remarks: *Ingredient is on additive basis in composition. Average nominal coating 5.77% Centralite No. 2. Total ether extract 6.38%

Inspector of Ordnance U. S. Chemist

Frankford Arsenal Stock No. LI-90130

OD FORM 18 Apr. 52 1204	ORDNANCE CORPS PROPELLANT DESCRIPTION SHEET	Supersedes OD Form 1204 dated 1 Jul. 49 which is obsolete.

U.S. Army Lot No. Not Issued of 1960 Composition No. CR-7787 For 20 mm
Lot 4 of E. I. du Pont de Nemours & Co.
Manufactured at: Carney's Point, N. J. Packed Weight 3.0001bs
Contract No. Date Specification No. Revision of
NITROCELLULOSE DA-36-038-507-ORD-3413/N
Accepted blends (Nos.) 2214

Nitrogen Content	K. I. Starch Test (65.5° C.)	Stability Test (135° C.)
Maximum %	Maximum Min.	Maximum Min.
Minimum %	Minimum Min.	Minimum Min.
Average 13.14 %	Average 37 Min.	Average 30 Min.
		Explosion Min.

MANUFACTURE OF PROPELLANT

Total weight of solvent per pound NC 0.92 Consisting of 35 pounds alcohol and 65 pounds ether per 100 pound solvent. Percentage of each to whole

TEMPS. °C. Dry	TEMPS. °C. Wet	PROCESS—SOLVENT RECOVERY AND DRYING	TIME Days	TIME Hours
35	55	Solvent Recovery		20
	55	Water drying, before coating	3	
	55	Water drying, after coating		24
	55	Air drying		19

TESTS OF FINISHED PROPELLANT

COMPOSITION Constituent	Formula	Min.	Impr.
Nitrocellulose	100.0	91.58	
Potassium Sulphate*	2.0	0.96	
Pulverized Tin*	1.0	0.73	
Diphenylamine*	1.0	0.70	
Centralite No. 2		5.89	
Total volatiles		1.05	
Moisture CCl4 dist.		0.80	
Ash		0.10	
Residual Solvent		0.25	

STABILITY AND PHYSICAL TESTS	Min.	Impr.
135° C heat test, E. P.	35'	
Explosion	5 + hrs.	
Form of grain	Cylindrical	
No. of perforations	1	
No. of grains per pound	175.883	
Burning surface per pound (sq. inches)	2232	
Grav. density, [illegible]	943	
Specific gravity Dust & fgn mat	0.02%	
Hygroscopicity		
Compression test Graphite	0.12%	

GRAIN DIMENSIONS	DIE (INCHES)	FINISHED GRAIN (INCHES) Manufacturer	FINISHED GRAIN (INCHES) Inspector	MEAN VARIATION IN PER CENT OF MEAN DIMENSION Manufacturer	MEAN VARIATION IN PER CENT OF MEAN DIMENSION Inspector
Length (L)	.0625	.0581			
Diameter (D)	.070-.075	.0451			
Diameter of perforations (d)	.015	.0076			
Web: Inner					
Web: Outer					
Web: Average		.0184			
Web: Calculated					
Difference between inner and outer web in per cent of web average					
L:D (Y)					
D:d (X)					

Date packed 9/23/60 Date offered Date sampled
Date test finished Date description sheets forwarded
Type of Packing Box Tinned-copper lined boxes
Remarks: *Indicates ingredient is on additive basis in composition
Total ether extract 6.52%. Average Nominal Coating 3.92%

Inspector: Neil C. Miller | Inspector of Ordnance | U. S. Chemist

Frankford Arsenal Stock No. LI-90131

CO FORM 1204 15 Apr. 52

ORDNANCE CORPS

PROPELLANT DESCRIPTION SHEET

Supersedes OO Form 1204 dated 1 Jul. 49 which is obsolete.

U.S. Army Lot No. Not Issued of 1960 Composition No. CR-7814 For PD mm

Lot 2 of E. I. du Pont de Nemours & Co., Inc.

Manufactured at: Carney's Point, N. J. Packed Weight 1500#

Contract No. Date Specification No. Revision of

NITROCELLULOSE DA-36-038-507-ORD-3413/N

Accepted blends (Nos.) 2214

Nitrogen Content	K. I. Starch Test (65.5° C.)	Stability Test (135° C.)
Maximum %	Maximum Mins.	Maximum Mins.
Minimum %	Minimum Mins.	Minimum Mins.
Average 13.14 %	Average 37 Mins.	Average 30 Mins.
		Explosion Mins.

MANUFACTURE OF PROPELLANT

Total weight of solvent per pound NC 0.92 Consisting of 35 pounds alcohol and 65 pounds ether per 100 pound solvent. Percentage of ranix to whole

TEMPS. °C From	TEMPS. °C To	PROCESS—SOLVENT RECOVERY AND DRYING	TIMES Days	TIMES Hours
35	55	Solvent Recovery		20
	55	Water drying, before coating	3	
	55	Water drying, after coating		24
	55	Air drying		17

TESTS OF FINISHED PROPELLANT

COMPOSITION % Constituent	% Formula	% Mfr	% Inspr.
Nitrocellulose	100.0	91.74	
Potassium Sulphate*	2.0	0.95	
Pulverized Tin*	1.0	0.63	
Diphenylamine*	1.0	0.71	
Centralite #2		3.92	
Dibutylphthalate*	2.0	1.92	
Total volatiles		1.15	
Moisture CCl_4 dist.		0.77	
Ash		0.10	
Residual Solvent		0.38	

STABILITY AND PHYSICAL TESTS	Mfr.	Inspr.
135° C heat test, S. P.	35'	
Explosion	5 + hrs.	
Form of grain	Cylindrical	
No. of perforations	1	
No. of grains per pound	178.722	
Burning surface per pound (sq. inches)	2397	
Grav. density, dynamometer	946	
Specific gravity Dust & fgn mat	0.02%	
Hygroscopicity		
Compression test Graphite	.11	

GRAIN DIMENSIONS	DIE (INCHES)	FINISHED GRAIN (INCHES) Manufacturer	FINISHED GRAIN (INCHES) Inspector	MEAN VARIATION IN PER CENT OF MEAN DIMENSION Manufacturer	MEAN VARIATION IN PER CENT OF MEAN DIMENSION Inspector
Length (L)	.0625	.0589			
Diameter (D)	.070-.075	.0466			
Diameter of perforations (d)	.015	.0080			
Web: Inner					
Web: Outer					
Web: Average		.0124			
Web: Calculated					
Difference between inner and outer web in per cent of web average					
L:D (Y)					
D:d (X)					

Date packed 9/23/60 Date offered Date sampled

Date test finished Date description sheets forwarded

Type of Packing Box Tinned-copper lined boxes.

Remarks: Total Ether Extract 6.47%. *Indicates ingredient is on additive basis in composition. Ave. nominal coating 4.34% Centralite #2

Superintendent: Wm C. Miller

Inspector of Ordnance

U. S. Chemist

Frankford Arsenal Stock No. YY-30152

Propellant Description Sheet for X2048 and Typical WC870 Propellant

Composition (%)	X-2048	WC870 AL 42747
Nitrocellulose nitrogen	13.15	a
Nitrocellulose	a	81.01
Nitroglycerin	8.48	8.85
Dibutylphthalate	7.95	6.22
Diphenylamine	0.89	0.86
Dinitrotoluene	0.50	0.73
Potassium nitrate	0.60	0.73
Potassium sulphate	0.42	0
Tin dioxide	0	0.77
Screen Analysis (% Retained)		
Screen Opening (in.)		
0.0469	0.1	0.00
0.0394	0.5	0.00
0.0331	15.0	9.47
0.0280	46.3	50.86
0.0232	37.5	38.81
0.0197	0.3	0.67
0.0165	0.2	0.19
Pan	0.1	0.00
Stability and Physical Tests		
120° C Heat Test (minutes)		
SP	60	65
RF	180+	a
Exp	300+	300+
Form of grain	Rolled	Ball
Web (in.)	0.020	-
Gravimetric density (gm/cc)	0.942	0.934
Specific Gravity (gm/cc)	1.58	a

[a]Not reported

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R-1613

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DEVELOPMENT AND ENGINEERING TEST OF NEW COOL BURNING EXTRUDED AND ROLLED BALL TYPE PROPELLANTS FOR 20MM AIRCRAFT AMMUNITION
by A. Victor Nardi

Report R-1613, February 1962, 25 pp incl tables,
OMS 5530.21.601, DA Proj 504-05-029
UNCLASSIFIED REPORT

Two new single base extruded propellants were developed for 20mm ammunition. CR7787 a centralite coated propellant and CR7814 an internally deterred and centralite coated propellant. A new rolled ball propellant X2048 had also been developed for 20mm ammunition. Propellants CR7787 and CR7814 with respect to erosion are greatly superior to IMR7005 propellants and are superior to the previously developed propellant CR7695. Propellants CR7787 and CR7814 apparently meet all the requirements for 20mm aircraft ammunition.

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1. Propellants for Aircraft Ammo
2. Cool Burning Extruded Propellants
3. Ball Type Propellants, Rolled
4. Aircraft Ammunition, 20mm

I. Nardi, A. Victor
II. OMS Code 5530.21.601
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3. Ball Type Propellants, Rolled
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The new double base rolled ball propellant X2048, with respect to erosion, is superior to the standard ball propellant WC870; and apparently meets all the requirements for 20mm aircraft ammunition.

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R-1613 (Cont'd)

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